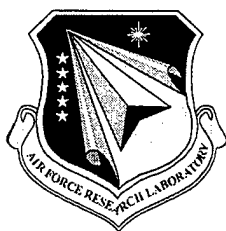


## **IBSS Low light Level Television Baffle Design**

**Willard F. Thorn**

**13 Dec 1998**

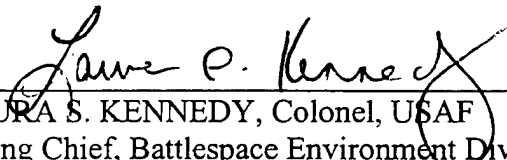
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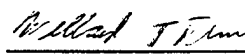



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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE December 1998		3. REPORT TYPE AND DATES COVERED Scientific, Interim
4. TITLE AND SUBTITLE IBSS Low Light Level Television Baffle Design			5. FUNDING NUMBERS PE 612303 PR 2303 TA GJ WU 01	
6. AUTHOR(S) Willard F. Thorn				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory/VSBP 29 Randolph Rd Hanscom AFB, MA 01731-3010			8. PERFORMING ORGANIZATION REPORT NUMBER  AFRL-VS-TR-1999-1573 Instrumentation Papers, No. 350	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION AVAILABILITY STATEMENT Approved for public release; distribution unlimited			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This report describes the design and construction process for the IBSS Low Light Level Television camera baffles. IBSS is short for Infrared Background Signautre Survey, a space shuttle experiment. This design was done as a result of an earlier design that did not conform to the required specifications for off-axis radiation rejection. The description of the design process is followed by a description of the improvements made to increase the performance of the baffles.				
14. SUBJECT TERMS Low light level television (LLTV)      Baffle      Infrared background signature survey (IBSS)			15. NUMBER OF PAGES 16	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT  UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE  UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT  UNCLASSIFIED	20. LIMITATION OF ABSTRACT  UNL	

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# Acknowledgements

The baffle design was done with the assistance of:

Ray Russell and his associates at Aerospace Corporation

Robert Stuart at Systems Integration Engineering

Gerald Lamb at Nichols Research

## **1. TV SYSTEM AND DESIGN REQUIREMENTS**

The IBSS TV system used two low light level television (LLTV) cameras with different focal lengths. They were both intensified solid state cameras with automatic iris lenses. Both had to operate with bright off-axis sources such as the sun, moon and earth limb while observing a target or star field at much fainter brightness levels. The size of the baffles, both length and diameter, was limited by spacecraft constraints. The design was optimized within size limits and camera field of view.

## **2. BAFFLE DESIGN**

The baffles were originally designed and built under contract. This original design was based on baffle designs for an unrelated project. The design report for the original baffles suggested that sharpened vane edges contributed very little to the internal scattering of light. They were, therefore, ignored in the baffle performance predictions. Ray tracing was used to predict light attenuation. Each reflection provided a 95% reduction in light to the next ray. The original design had twelve vanes (ten internal plus two ends). Design theory indicated that more reflections equals better performance. In practice, our testing showed the edges were the principal contributor of poor off-axis performance due to their internal scattering of light. Initial testing showed that each time a vane was removed the performance improved. This indicated that less was better but not what was optimal.

The surface coating is important. With the correct choice of paint and surface preparation most of the light will be absorbed. Our choice was a NASA approved flat black paint that provided more than 95% absorption. The surface coating used had enough absorption that three reflections were determined to provide an acceptable level of light reduction. That is, 95% cubed, or 99.99%. Most of the light not absorbed is reflected in the specular direction. There is some diffuse reflection from this type of surface. It was a small enough portion that we were unable to detect any degradation from it. The diffuse reflected light was ignored in this design.

A minimum vane design was conceived to minimize edge scattering. The overall baffle dimensions were fixed by the spacecraft considerations. The lens focal lengths were also fixed by performance requirements. If optimal locations for vanes are used, a minimal number of vanes should be required. With the fixed components of the baffle determined, the optimum locations were searched for graphically by ray tracing.

The conceptual design using ray tracing was provided by drafting software. As various vane combinations were tried a theory of the minimum vane number and their spacing evolved. After the basic rules for minimal vanes were found the precise parameters were calculated. The equations below and accompanying figures show the resulting design. This design should be applicable for similar "three reflection" baffles of circular field of view. (The TV picture is rectangular. Slightly better performance could have been obtained with rectangular baffles. The increase in complexity was not justified by the increase in system performance.)

The baffle length and diameter are physical constraints on system size. They should be as large as possible. Vanes 1 and N (N being the vane defining entrance aperture) are determined by the ends of the baffle and the field of view. Vane 1 should be as close to the lens as possible. Vane N should be as far from the lens as possible. With this information it was possible to mathematically determine the optimum location of each internal vane.

The critical reflection point, CP (see Figure1) is the point where light entering off-axis strikes the edge of vane #1. Rays from a shallower off-axis angle will result in the vane nearest the lens catching the light. Greater off-axis angles will result in light entering the lens with one reflection. Since our design requires three reflections, a vane must be introduced to prevent this. The critical reflection point can found with equation 1. It predicts the distance from vane #1 to the critical reflection point CP, which would lead to light reflecting into the lens.

$$B = (A * L) / (A + A') \quad 1$$

Start with a baffle having only the two end vanes, as determined by the dimensional constraints on the design. These are 1 and N (see Figure 2). It is necessary to call it N at this point in the design because the total number of vanes required is not known. In equation #1 A and A' are related to the two end vane dimensions, and L is the overall length between the two end vane edges. Having found the critical reflection point CP, the vane location and hole size can be specified. The edge of the vane must be at the intersection of the edge of the field of view and the light ray to the critical reflection point.

An X, Y coordinate system with the origin at the baffle corner can be used to simplify the calculation. The critical light ray may be described by equation 2.

$$Y = (A / B) * X - A = \tan(a) * X - A \quad 2$$

The edge of the full angle field of view (FOV) may be described by equation 3.

$$Y = (-\tan(FOV / 2)) * X + A \quad 3$$

Solving these two simultaneous equations results in Y, the vane height, and X, the vane location, both relative the xy origin, at the corner.

These calculations must be repeated for each internal vane. The calculations are simplest if the coordinate system is moved to the position of the last vane edge calculated and all variables redefined to the remaining baffle length and vane sizes.

The number of internal vanes will vary with the field of view, the baffle diameter, and the baffle length. Vane N-1, the second farthest from the lens, is the last one needed to prevent a single reflection to the lens. Once no rays can reach the lens with less than three reflections no more vanes should be added. This will result in the minimum number of vanes and still require at least three reflections before off-axis light reaches the lens. The resulting set of vanes is shown in Figure 3.

### 3. CONSTRUCTION

The baffles were constructed of 6060-T6 aluminum. There are other materials that would provide a sharper vane edge (for example steel). They have other less desirable qualities (such as weight in the case of steel).

Each vane was machined sandwiched between aluminum plates in order to provide support for the edge as it was machined. The sandwich prevented the edge from rolling or burring as it was sharpened. This resulted in a very sharp edge when the vane was removed from the sandwich.



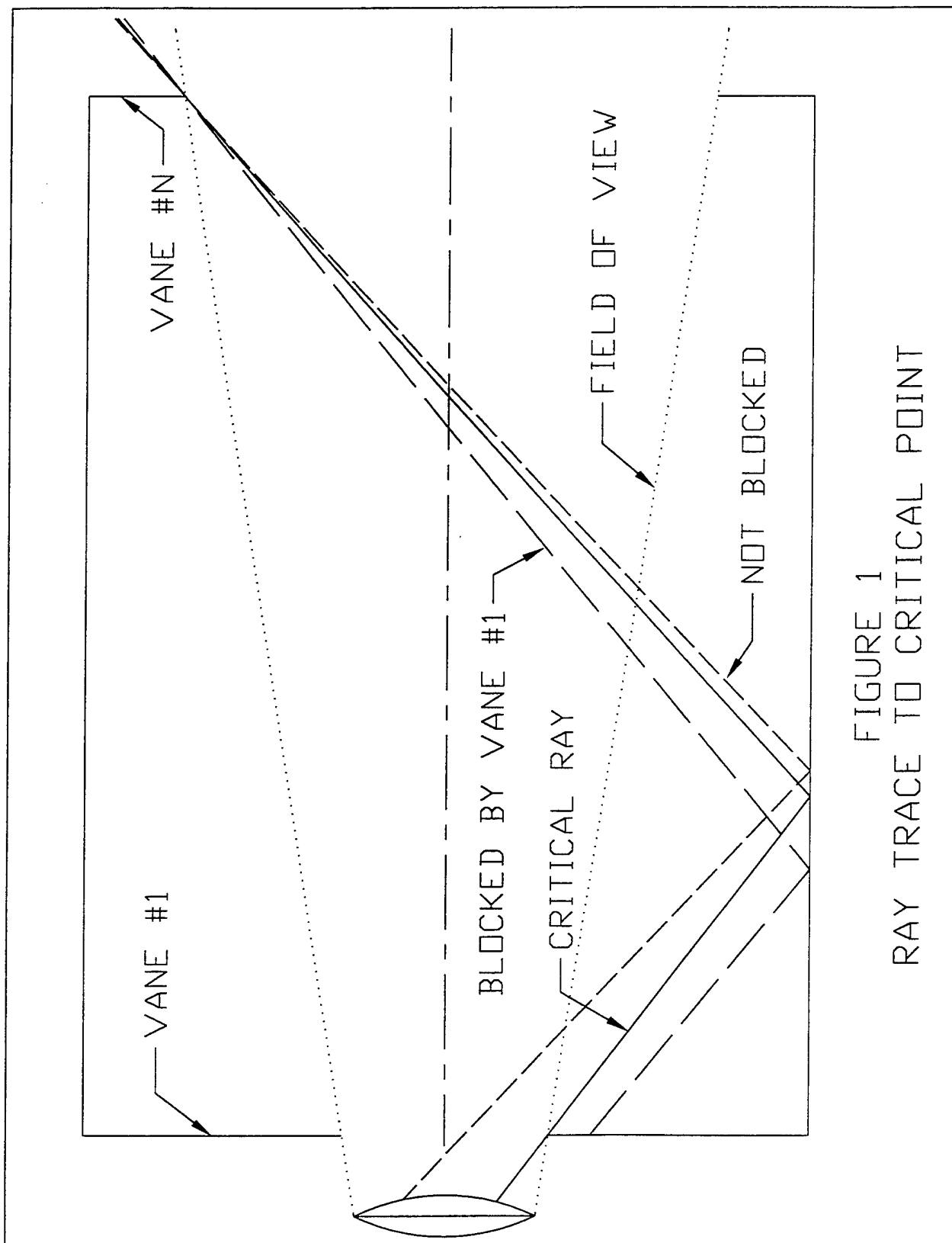


FIGURE 1  
RAY TRACE TO CRITICAL POINT

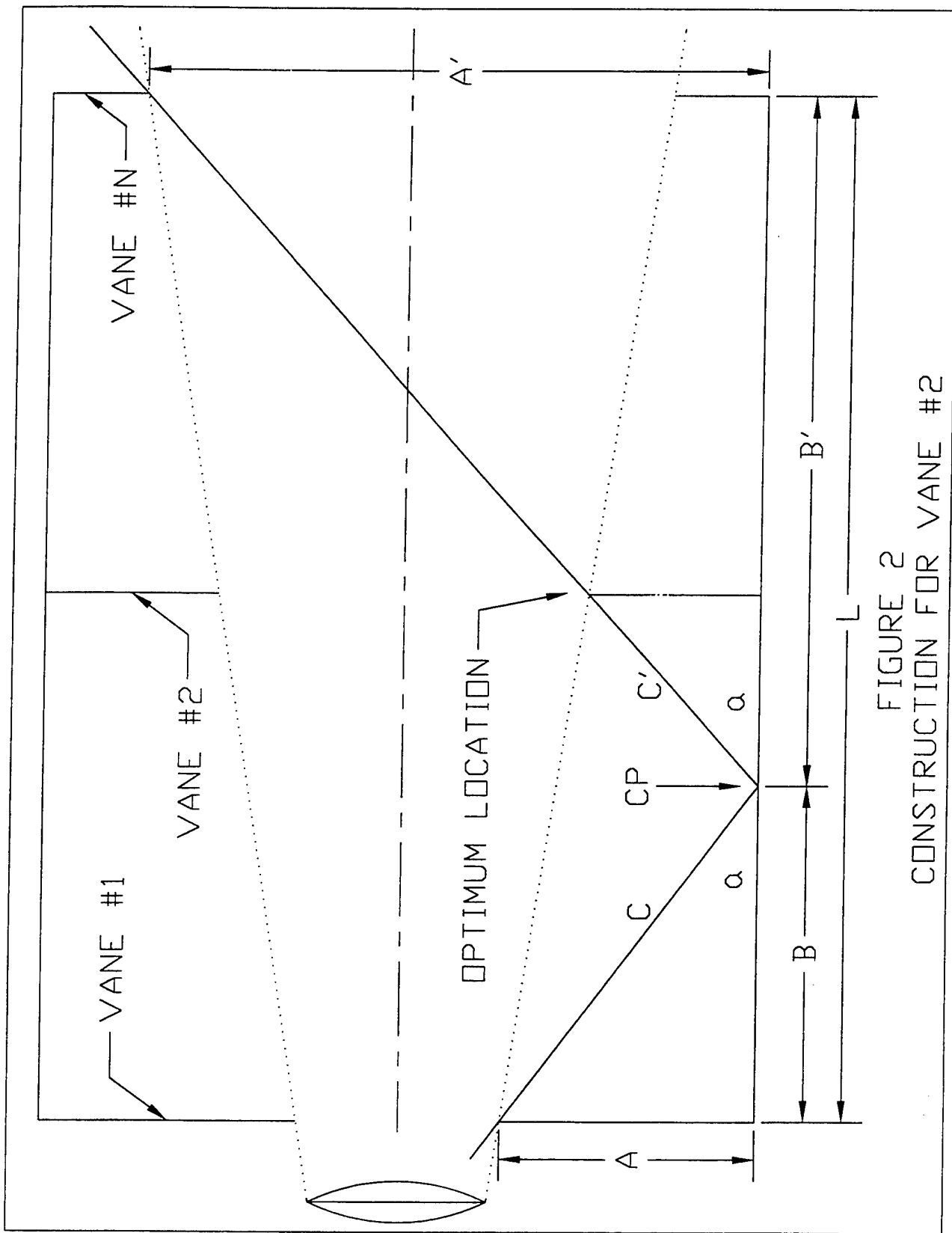


FIGURE 2  
CONSTRUCTION FOR VANE #2

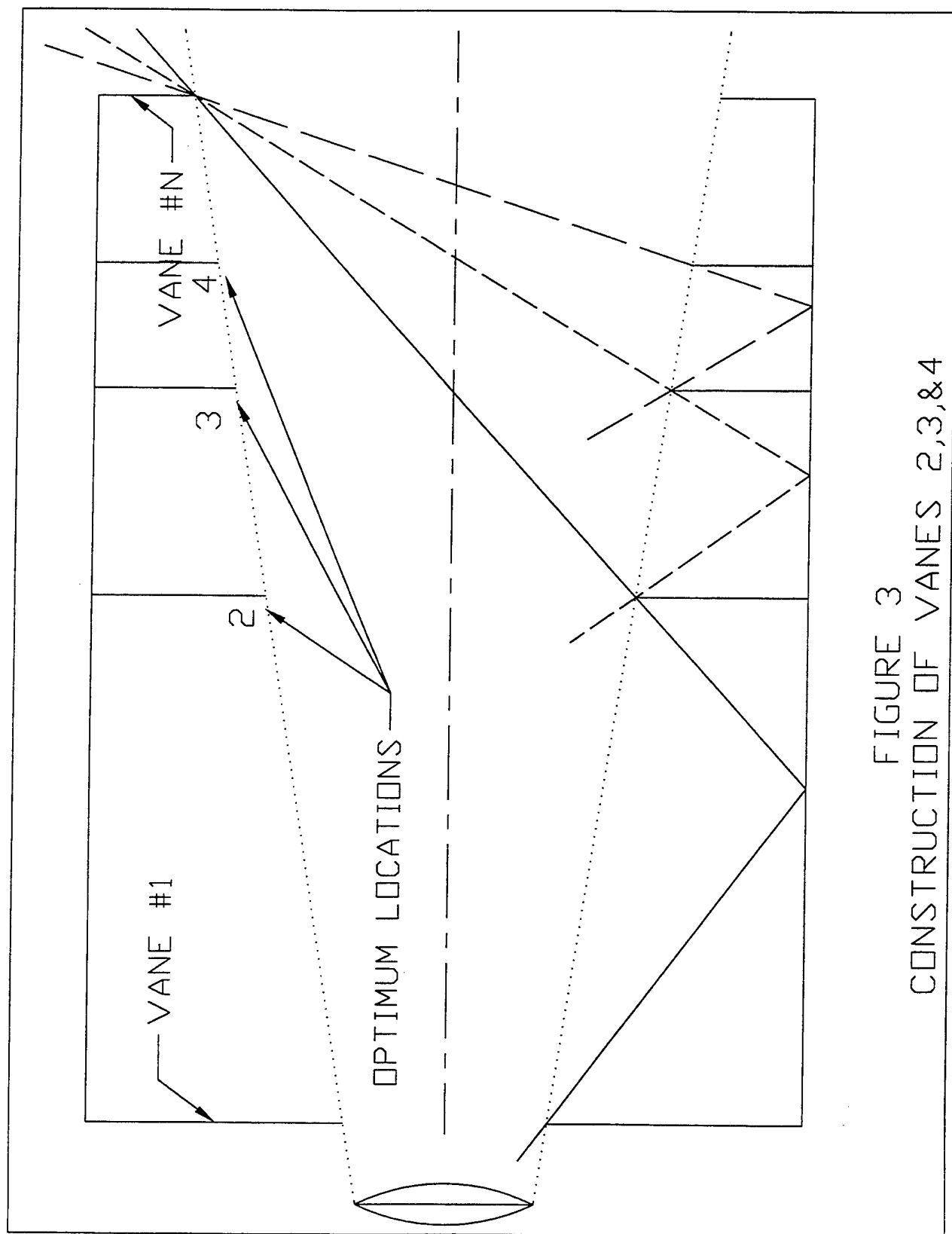


FIGURE 3  
CONSTRUCTION OF VANES 2,3,&4

The housing of the baffle was an aluminum tube. The end vane, #1, was combined with the mounting flange. It was electron beam welded to the end of the tube. The other end, vane N was held to the tube with screws. The internal vanes were spaced with smaller tube sections that were a tight slip fit inside the housing tube. The actual vane spacing was slightly less than called for in the calculations. This was to compensate for machining tolerances expected during construction. Slightly closer spacing of the vanes did not require an additional vane. The vane edge must be beveled. The vanes have thickness, so the sharp edge must be located where the calculations direct. The bevel on the vane edge must be cut so as to prevent it from providing a reflection path to the lens. It was found that the outer vanes should have the bevel faced outward and the inner vanes beveled surfaces faced inward. This is contrary to common practice. When the first vane is placed with the bevel facing in, light striking it can be reflected directly into the lens. Vanes should be faced with the bevel out until it is not possible to illuminate the beveled face with off-axis light. The resulting arrangement is shown in Figure 4.

#### **4. SURFACE TREATMENT**

The design was based on an absorption greater than 95%. The following surface treatment provided the required absorption. All internal surfaces were lightly sand blasted. The sand blast surface provided better absorption in the near IR, as well as providing for better paint adhesion. Care was taken not to sand blast the sharp edge. All internal surfaces were painted with flat black paint, 3M Corporation ECP-2200. This paint went on thick, and had a tendency to ball up on the sharp vane edges. The excess paint resulting from this ball up had to be removed in order to keep the edge sharp. This was done by using #600 wet or dry sandpaper on the edge until the aluminum just began to show through at the edge. The width of the sanded area was less than 1/32 inch.

#### **5. RESULTS**

Testing was conducted in a dark room. A lamp simulating solar radiation was pointed at the baffle entrance. Difficulties were encountered trying to keep the dark room dark with a solar simulator on (this may sound like a dumb statement but was the most difficult part of the testing). The light source was baffled to illuminate the entire baffle aperture but very little else. At the same time a simulated target was imaged by the LLLTV camera. The baffle performance was measured by target image degradation.

The original testing was done with the first baffle design. The test results showed very poor baffle performance, far below the program requirements. When the solar simulator was turned on all but the brightest targets disappeared from the TV screen.

Tests of the new baffle design showed a dramatic attenuation of strong off axis sources through a wide range of angles. The final baffle design provided off axis protection to the degree that there was no detectable degradation. Off-axis protection was sufficient that the solar simulator, when 20 or more degrees out of the field of view, could not be detected in the TV image.

The new baffle design was a considerable improvement over the original baffle design with more than twice as many vanes. While this testing did not provide a numerical measure of baffle performance it did show that it would provide the required level of off-axis protection on orbit.

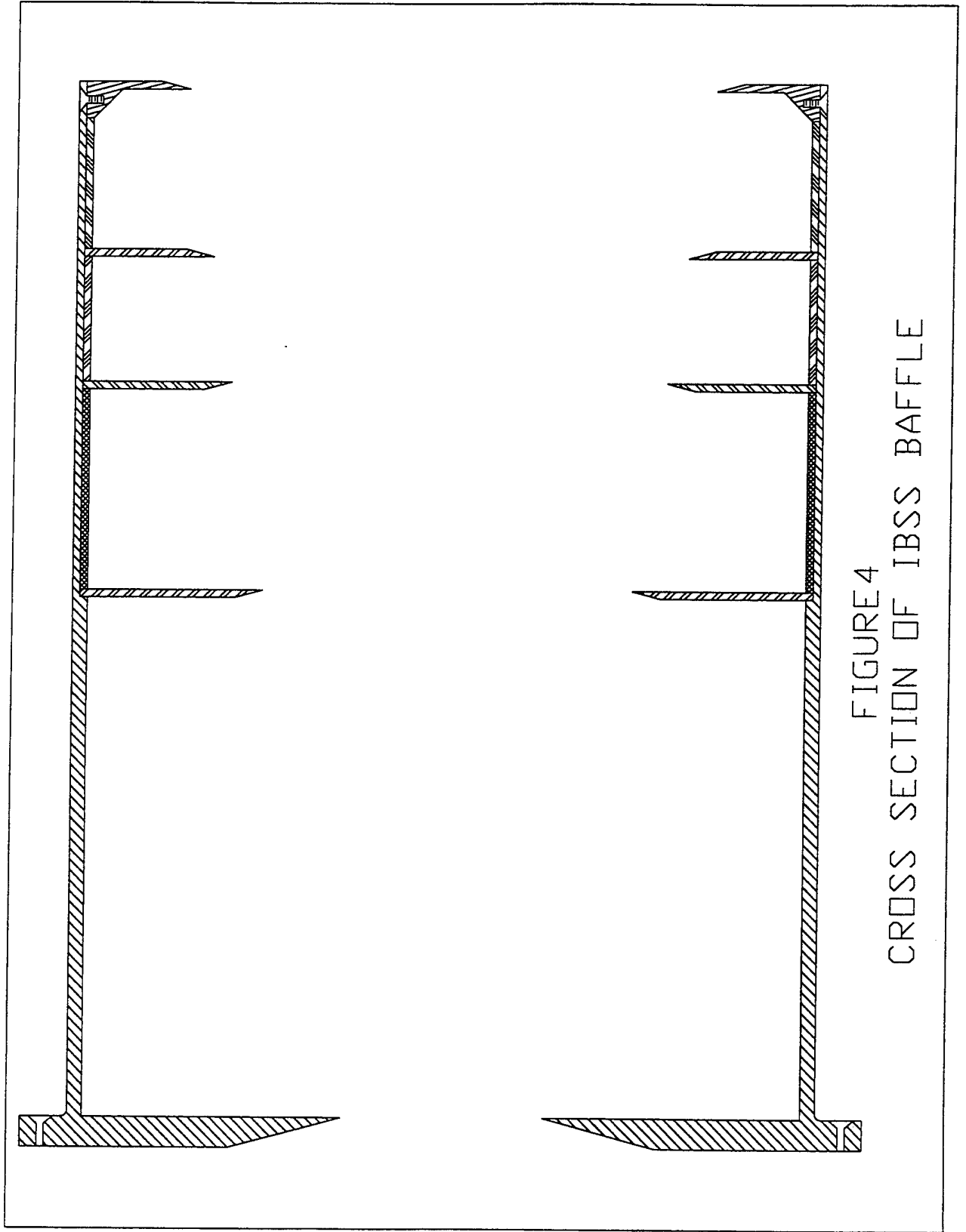


FIGURE 4  
CROSS SECTION OF IBSS BAFFLE

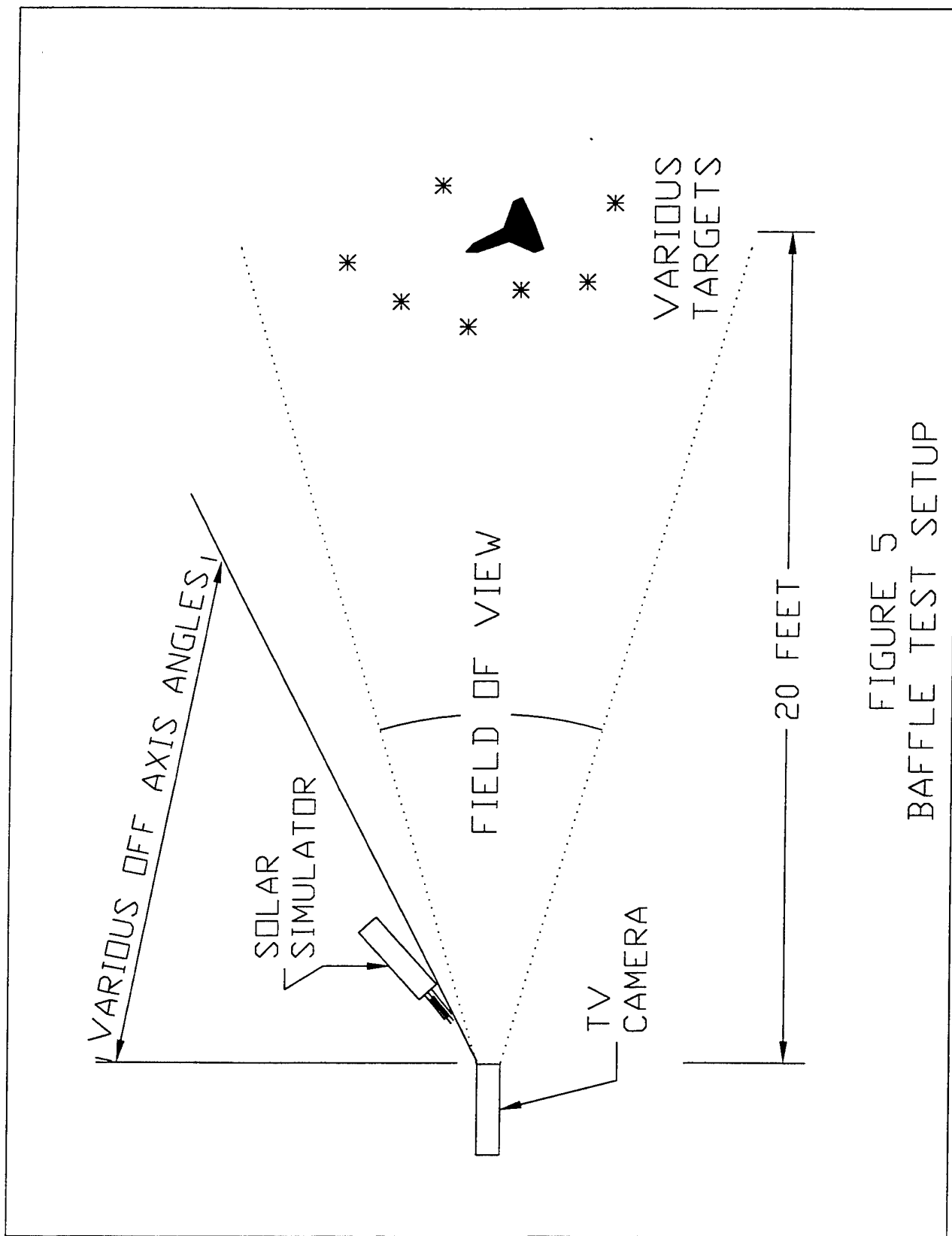


FIGURE 5  
BAFFLE TEST SETUP